Chapter 23
Farms and Forests: Spatial and Temporal Perspectives on Ancient Maya Landscapes

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23.1 Introduction

"Hills rose around us on every side, and, for that country, the scene was picturesque, but all waste and silent. The stillness of the grave rested upon the ruins, and the little notes of a flycatcher were the only sounds we heard" (Stephens 1843, p. 113). So wrote the American explorer John L. Stephens of his visit to the ruins of Xculoc, Campeche, Mexico in 1842. Through the works of Stephens, Waldeck, Maler, Maudsley, and other nineteenth century adventurers and scholars the ruins of ancient Maya Civilization were brought to the attention of the outside world (Wauchope 1965). It is perhaps these glimpses of forest-draped ruins that gave rise to the over-used epithet 'the mysterious Maya'. While such scenes of ancient cities moldering in the forest still exist in parts of the Maya Lowlands (Fig. 23.1), rapid repopulation and deforestation is transforming forest to fields and pastures and laying bare the relicts of the ancient Maya and a once densely populated landscape. This is not the first time that the Maya forest has been in retreat. In its multifarious forms, the forest has waxed and waned many times over the past several millennia, largely at the hands of the ancient Maya, though climate changes may also have contributed to changes in vegetative cover. In this light, the Maya are hardly mysterious. Over the centuries, like people everywhere they strove to wrest a living from their environment, adapted often with great success to the rhythms of the region's tropical wet-dry climate, and sometimes failed—episodes that were marked by human population decline and forest resurgence.

Over the past three decades, the spatially and temporally variable nature of the Maya Lowlands environment has become more widely appreciated, though it remains far from completely understood. A thorough review of the history of human-environment interactions in the Maya Lowlands is impossible in a few pages. In this chapter we highlight a few case studies that illuminate both the broader trends of that history as well as the nuances brought about in part by the varied nature of the lowland environment. Our review focuses particularly on the period from about 300 BC to around 900 AD; that is, from the Maya Late Preclassic through Terminal Classic period. It was during these 1400 years that Maya peoples accomplished their most enduring deeds in art and architecture, and during which their effects upon the landscape were most profound.

23.2 Environment and Cultural History

Much early scholarly thinking on Maya Civilization viewed the environment as static and culturally limiting, essentially a tropical forest prison that limited agriculture, population density, and urbanism. More recent scholarship has come to recognize the complexity of the Maya Lowlands environment and the varied ways in which the Maya transformed it. Increasingly, we are discerning the many and varied experiences of Maya populations in different places during the course of Maya Civilization.

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See Plate 21 in the Color Plate Section; also available at: extras.springer.com

I. P. Martini, W. Chesworth (eds.), *Landscapes and Societies,*
DOI 10.1007/978-90-481-9413-1_23, © Springer Science+Business Media B.V. 2010

Fig. 23.1 In 2004, forest still covered the ruins of the Plan de Ayutla acropolis (Chiapas, Mexico)

23.2.1 The Maya Lowlands Environment

The cultural region of the Maya Lowlands includes the Yucatan Peninsula, other low-lying contiguous areas of Central America, and a small area of higher elevation in the Maya Mountains (Fig. 23.2). Environmental factors that create a mosaic of habitats across the lowlands include variations in intra- and inter-annual rainfall, soil and geomorphic processes, and slope gradients and drainage conditioned by structural geology (Dunning et al. 1998; Beach et al. 2008). Only a few of the many habitats found in the region will be looked at in detail here, as we discuss examples of ancient Maya adaptations to their heterogeneous environment. Embedded in the development of all of these habitats,

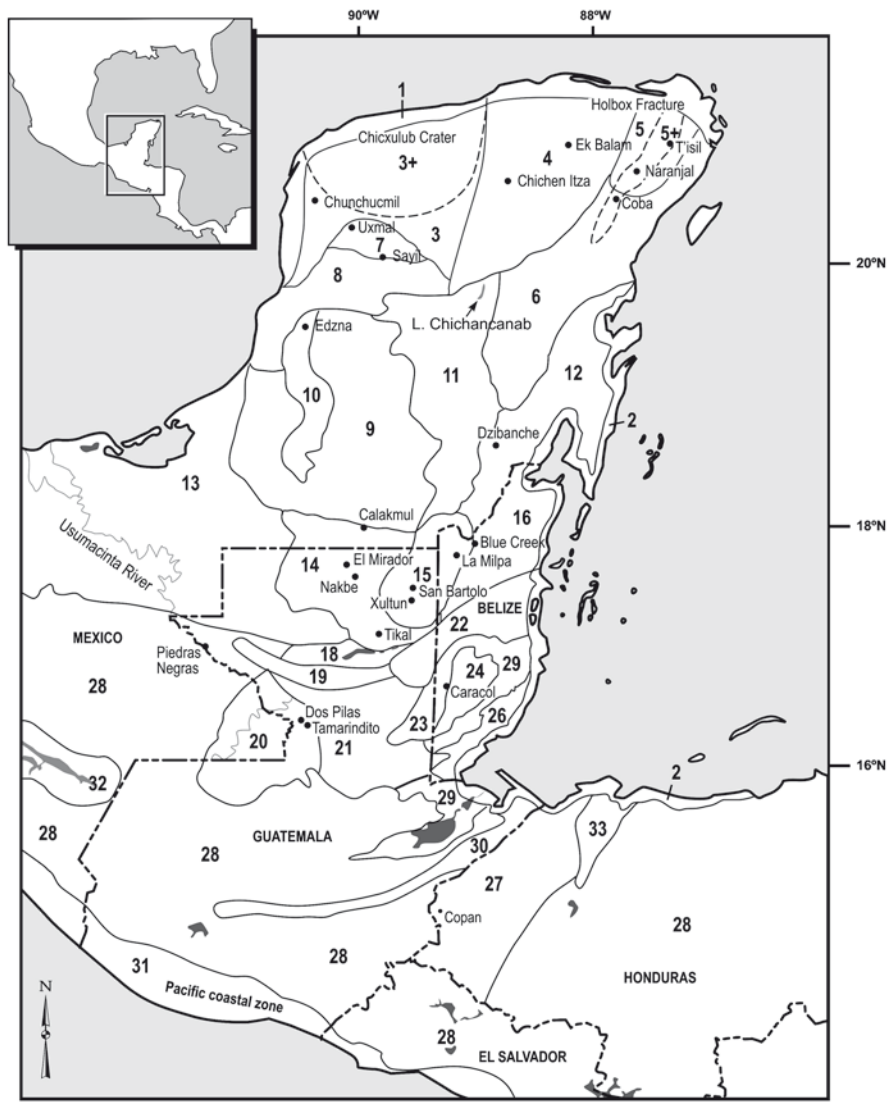

Fig. 23.2 Map of the Maya Lowlands showing physiographic sub-regions and sites mentioned in the text. (Numbers refer to sub-regions: *1* North Coast; *2* Caribbean Reef and Eastern Coastal Margin; *3* Northwest Karst Plain; *3+* Chicxulub impact feaure; *4* Northeast Karst Plain; *5* Yalahau; *5+* Holbox Fracture; *6* Coba-Okop; *7* Puuc-Santa Elena; *8* Puuc-Bolonchen Hills; *9* Central Hills; *10* Edzna-Silvituk Trough; *11* Quintana Roo Depression; *12* Uaymil; *13* Río Candelaria-Río San Pedro; *14* Peten Karst Plateau and Mirador Basin; *15* Three Rivers Horst and Graben; *16* Rio Hondo; *17* Lacandon Fold; *18* Peten Itza Fracture; *19* Libertad Anticline; *20* Río de la Pasión; *21* Dolores; *22* Belize River Valley; *23* Vaca Plateau; *24* Maya Mountains; *25* Hummingbird Karst; *26* Karstic Piedmont; *27* Motagua and Copan Valleys. (After Dunning et al. 1998; Beach et al. 2008)

of course, were humans, especially during the past three millennia of profound change.

Annual rainfall totals generally range from a low of about 500 mm in the northwest to a high near 2500 mm in the southern extremes of the lowlands. The intruding elevation of the Maya Mountains, however, induces more rainfall on their eastern flank (including the Hummingbird Karst and Karstic Piedmont) and a rain shadow to their west (Dolores region). Year-to-year variation is quite high, and Maya farmers have responded to this by developing many inventive approaches for managing risk. Furthermore, the distribution of rainfall is highly uneven throughout the year, with a pronounced and variable dry season generally from November through April.

Most of the Maya Lowlands is underlain by limestone, a simple fact with serious implications for human settlement because the regional geology exerts a strong influence on water movement. Across much of the peninsula drainage is largely subterranean with the karst interior acting as an enormous bedrock sponge for much of the region's rainfall. On the more arid northern plains freshwater is largely available sporadically in 'cenotes' (sinkholes). In the central interior of the peninsula, only a few deep caves and surface ponds ('aguadas') offer water in the dry season. In these elevated interior areas structural faulting as well as limestone and gypsum dissolution have created innumerable basins ('bajos') of varying size which drain entirely internally into the bedrock and are sometimes linked with one another by seasonal surface channels. In the wetter, more elevated south seasonal surface runoff and perennial spring discharge feed rivers including the Usumacinta and Candelaria to the west and the Hondo and Belize rivers to the east.

Broadly speaking, Maya Lowlands soils have relatively high fertility, and are well-drained, clayey, and calcareous, though they tend to be shallow. In the southern lowlands, soils are deeper, relatively poorly drained, and more leached and weathered but still clayey and calcareous. Within the lowland subregions, geologic structure is an important factor that creates variation in the spatial distribution of soils because of its influence on drainage and slope gradient as well as the age of soilscapes. Faulting and fracturing have created a landscape with enough variation in drainage to have produced a mosaic of land surfaces that vary from well drained uplands with generally shallow, but fertile Rendoll soils, to areas of seasonal inundation with deeper Vertisols (shrinking and swelling clay soils) such as in the interior bajos, and some perennially flooded wetlands with water-logged, organic Histosols (Dunning et al. 1998). Natural vegetation across the Maya Lowlands follows rainfall patterns and the seasonality of water supply, though edaphic factors, like soil drainage and chemistry, cultural factors, and lithology are also influential (Greller 2000). From the northwest coast of Yucatan southward through the peninsula, the beach ridges of the coast merge into a 10–20 km swath of swampy estuarine wetlands, and a thorn woodland-savannah that grades into a dry, deciduous, seasonal forest in the central peninsular uplands. The deciduous forest then grades into tropical, dry forest that stretches from central Yucatan into the northern Peten District of Guatemala. This dry forest breaks up into a savannah zone centered on the La Libertad Anticline, which grades southward into the species-rich, tropical, moist forest of the wetter southern half of the Peten. These forests are not truly tropical rainforests, but they have diverse species assemblages nonetheless (Greller 2000). An east to west rainfall gradient also leads to more evergreen forms of vegetation in the east and more xerophytic forms in the west particularly in the northern portion of the peninsula.

23.2.2 Cultural History

Pre-Hispanic human occupation of the Maya Lowlands is often divided into the following chronological periods:

- Pre-7000 BC: PaleoIndian
- 7000–2200 BC: Archaic
- 2200 BC–250 AD: Preclassic
  - 2200–1000 BC: Early Preclassic
  - 1000–400 BC: Middle Preclassic
  - 400 BC–100 AD: Late Preclassic
  - 100–250 AD: Terminal Preclassic
- 250–900 AD: Classic
  - 250–600 AD: Early Classic
  - 600–770 AD: Late Classic
  - 770–900 AD: Terminal Classic
- 900–1500 AD: Postclassic
  - 900–1250 AD: Early Postclassic
  - 1250–1500 AD: Late Postclassic.

Portions of this chronology were established on the basis of older thinking about the Maya, particularly

the definition of a Classic period as the time characterized by the erection of carved stelae with dated hieroglyphic inscriptions. Stelae and inscriptions are now known from both the Preclassic and Postclassic periods. Similarly, both population numbers and cultural accomplishments were once commonly believed to have peaked throughout the Maya Lowlands in the Late Classic, followed by population collapse and cultural decline. Scholars now understand that the course of Maya Civilization was much more complex. Major population apogees and ensuing collapses occurred in both the Terminal Preclassic and Terminal Classic periods, with lesser fluctuations at the end of the Middle Preclassic and Early Classic. This population growth and decline, however, was not uniform across the entire lowlands. In each period, some sites and regions experienced greater growth or more complete abandonment than their neighbors while others experienced much less fluctuation. Some regions were abandoned for hundreds of years at a time, while others were never abandoned. In part, this spatial variability in population patterns through time reflects the underlying mosaic of habitats with the lowlands, as well as pan-regional climate pulses. Environmental variables, however, can explain only some of the patterning because human response and adaptation played a major role in the turbulent course of Maya history (see Demarest (2005) and Webster (2002) for more discussion on Maya cultural history).

23.2.3 Environmental Change

Scholarly thought on the role of environmental change over the course of Maya Civilization has evolved (Dunning and Beach 2004). For much of the twentieth century, scholars treated the tropical Maya Lowlands environment as largely unchanged over time. It is now recognized that the region's environment has been very dynamic over both long and short time scales. For instance, recent studies have brought attention to the ongoing impacts of the massive Chicxulub meteorite, which struck near the north end of the peninsula at the end of the Cretaceous, some 65 million years ago, and is implicated in the demise of the dinosaurs. Some attributes of the region owe their origin to orbitally-driven, long-term climate fluctuations that influenced global sea-levels and the emergence/submergence of the Yucatan Platform and its composition. More recently, the submergence of large portions of the platform with sea-level rise at the end of the Pleistocene (~17,000–10,000 years ago) and during the early Holocene (ca. 10,000–5000 years ago), as well as establishment of a generally warm, humid climate about 10,000 years ago, had important impacts on human settlement of the peninsula. Continued climate and environmental changes in the Preclassic and Classic compelled the Maya to adapt to continued slow sea level rise and spread of wetlands in the coastal plain. Although large volcanic eruptions devastated parts of the Maya Highlands, as yet there is little evidence for deleterious effects of volcanic activity in the limestone lowlands.

On long time scales, thousands to tens of thousands of years, climate in the Maya Lowlands has been quite variable. For instance, sediment cores from Lake Peten-Itza in northern Guatemala suggest there were dramatic changes in temperature and moisture availability during the last 85,000 years (Hodell et al. 2008). Even since the onset of the Holocene, climate conditions have also displayed considerable variability, especially with respect to effective rainfall (Brenner et al. 2002; Hodell et al. 2005). Wetter conditions in the mid-Holocene gave way to a general, progressive drying trend that began about 4000 years ago (Mueller et al. 2008). For the late Holocene, it has been proposed that short-term (centennial) fluctuations in rainfall may have been driven by the 208-year cycle of solar output (Hodell et al. 2001; Wahl et al. 2006). Such cycles may account for droughts in some areas of the lowlands, and may have had significant impacts on Maya populations (Gill 2000; Hodell et al. 2005; Haug et al. 2003). Accumulating paleoenvironmental data indicate that periods of particularly intense drought may have afflicted wide areas of the Maya Lowlands in the fourth century BC, and the second, sixth, ninth and eleventh centuries AD, as well as the Little Ice Age. These were not single megadroughts, but clusters of increased drought frequencies.

Even today, modern instrumental records from the Maya Lowlands indicate the region is characterized by large variations in rainfall from site-to-site, year-to-year, and across seasons. Inter-annual variation in rainfall can be large, on the order or 30–40%, and this spatial and temporal variability in precipitation undoubtedly played an important role in Maya agricultural strategies over time. Another potentially destabilizing and largely unpredictable aspect of Maya Lowlands climate is hurricanes. In recent times, major hurricanes have raged

across the region frequently (for example, Gilbert in 1988, Mitch in 1998, and Isadora in 2002), bringing a combination of wind damage, flooding, catastrophic crop loss, and population displacement. The ancient Maya perceived this violence as akin to divine warfare.

The ancient Maya themselves were agents of both regional and local environmental change, which has been recognized for many years (Deevey et al. 1979). In particular, deforestation and soil erosion have been cited as environmental factors that might have negatively affected Maya subsistence options (Beach and Dunning 1995; Dunning and Beach 2004). The relationship between human population density and environmental disturbance has proven to be more complex than previously envisioned. The relationship between population numbers and environmental degradation is rarely linear, as we shall see in the following sections.

23.3 Preclassic Landscapes

For many years, scholars viewed the Preclassic period as one of essentially slow, steady population growth, largely pre-urban settlement organization, and relatively minor environmental impact. That perspective has changed radically over the past 20 years with more investigations targeting the earlier periods of Maya Civilization. Archaeologically, such investigations are hampered because Preclassic materials are often buried under later Classic constructions. Similarly, the environmental changes triggered by Preclassic peoples are often masked by later changes. Nevertheless, we are now beginning to understand these early times including climatic perturbation, the origins of urbanism, the diffusion and development of agriculture, and the dramatic impacts on local and regional environments brought about by forest clearance, population concentration, conservation practices, and monumental urban construction.

23.3.1 Lake Tamarindito

Lake Tamarindito lies in a structural depression 100 m below the Petexbatun Escarpment, and adjacent to the ancient town of Tamarindito in the southwestern part of Guatemala's Peten District. Sediment cores from this small lake provided evidence for long-term human–environmental interactions (Dunning et al. 1998). Although the intended focus of that research was the Late Classic period, the Lake Tamarindito cores contained a paleoenvironmental record reaching back over 10,000 years, to the onset of the Holocene. The lower portions of the cores record the origins of the lake from a dry, elevated depression in the late Pleistocene, to a water-filled basin that accumulated sediments as wetter conditions developed during the Holocene. Pollen grains from the lower depths of the core show the establishment of a regional, species-rich, tropical moist forest. The first evidence of human impacts appears in the Late Archaic, after about 4000 BP in the form of slightly increased levels of inorganic sediment inputs, greater charcoal concentrations, and increased relative abundance of grass pollen indicative of the first episodes of forest clearance or climate drying in the region. Definite evidence of agriculture makes its first appearance with *Zea mays* (corn) pollen about the same time. Maize production has been documented palynologically between 5000 and 3000 BP at many sites in the Maya Lowlands. Figure 23.3 represents data from the sections of the 1995B core from about 1200 BC to about 400 AD.

For much of this period, archaeological evidence indicates that permanent human settlements were largely confined to the shores of Lake Petexbatun and the Río Petexbatun, some 2–3 km east of Lake Tamarindito. Notably, human impacts detected in the Lake Tamarindito sediments are expressed as pulses of forest clearance and regrowth, though overall there is a diminution in forest plants and an increase in disturbance taxa and cultigens over time. Changes in the species-composition of the disturbance taxa (weeds) indicates that field fallow times decreased over time, probably culminating in the establishment of a largely fixed field agricultural system by ~100 AD. Around that time, the ratio of forest and field indicators in the pollen record largely stabilized. Arboreal species overall remained diminished, though far from absent, and the number of economically valuable tree species was greater than during pre-Maya times. In combination, the pollen data indicate that by the onset of the Early Classic period around 250 AD, the landscape around Lake Tamarindito consisted largely of fixed, or short-fallow agricultural fields and sizeable patches of managed forest (essentially woodlots and orchards).

Similarly, shifting rates of inorganic sediment accumulation into Lake Tamarindito indicate pulses

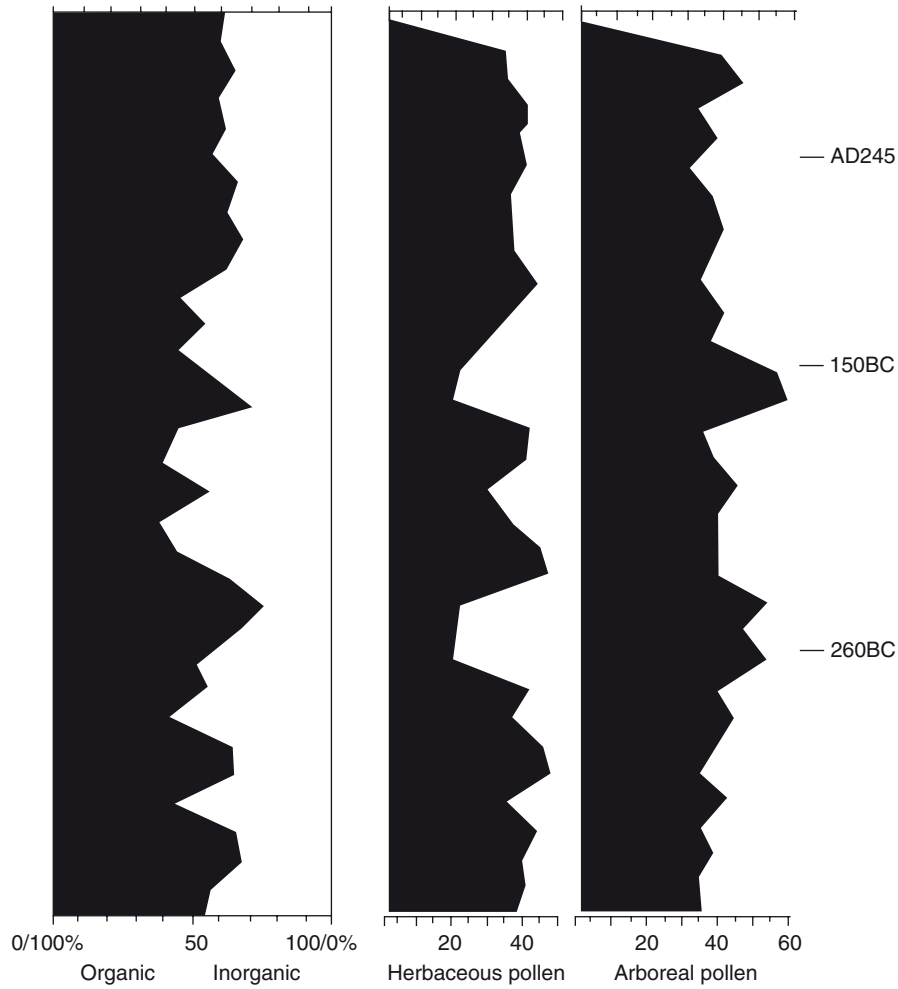

Fig. 23.3 Sediment composition and pollen frequency diagram for a sediment core extracted from Lake Tamarindito, Guatemala in 1995. Inorganic sediments are dominantly silicate clays with minor amounts of calcium carbonate and iron oxide. Dates are calibrated radiocarbon intercepts. Pollen analysis by David Rue (Archaeological and Historical Consultants, Inc., Centre Hall, PA) and John G. Jones (Department of Anthropology, Washington State University)

of forest clearance and spikes in soil erosion during much of the Preclassic. By around 100 AD, inorganic sediment input into the lake was about 25 times higher than in pre-and post-Maya times. During the ensuing Early Classic period, sediment inputs actually decreased, probably due, in part, to the development of soil conservation terracing practices on nearby sloping lands, which we discuss later. This picture of landscape stability at the end of the Late Preclassic stands in sharp contrast to environmental conditions in some other regions of the Maya Lowlands at this time.

23.3.2 Mirador Basin

About 130 km north of Tamarindito in the northernmost portion of the Peten District lies the Mirador Basin (Hansen et al. 2002; Wahl et al. 2006). It is a large, elevated subsidence basin with numerous, irregularly distributed bajos of varying size and internal, karst drainage. Archaeologically, the region is known for its numerous and very large Preclassic centers, the two most investigated being Nakbe and El Mirador. Nakbe was a large town by the Middle Preclassic (ca. 700 BC), while El Mirador rose to become the dominant center of the basin, and likely the Southern Maya Lowlands, by the Late Preclassic (ca. 300 BC). Despite its early grandeur, much of the Mirador Basin was largely abandoned by around AD 150. We still know little about the residential or sustaining areas that lay beyond the core of these sites. El Mirador, Nakbe, and other large sites in the region are perched on the edges of relatively large bajos. Paleoecological data from the bajo adjacent to Nakbe include two important findings. First, this depression once contained larger areas

of biologically productive perennial wetlands than are found there today, and which may have occurred in other bajos of the Mirador Basin. Second, the degradation of this resource may have contributed to the abandonment of the region towards the end of the Late Preclassic (Hansen et al. 2002; Wahl et al. 2006).

The monumental architecture, most notably the triadic pyramid complexes of El Mirador, include the largest masonry structures ever constructed in the Maya Lowlands. The Dante Complex at El Mirador alone contains some 2.8 million m^3 of masonry, and other architectural groups at El Mirador and other sites in the region were not far behind in size. The Preclassic architecture of the Mirador Basin is notable for the enormous quantities of lime plaster that cover relatively crude stonework and form the decorative masks and other stucco ornamentation. One study by Thomas Schreiner concluded that it would have been necessary to cut down a large part of the region's forests to fuel fires needed to burn limestone and produce plaster. Indeed, large ancient quarries are still evident across the region today, and many adjacent bajos show evidence of massive influxes of eroded sediment (Hansen et al. 2002; Wahl et al. 2006). In essence, the glorification of deities and divine kings through the erection of ever-larger buildings may have spelled doom for the populace of the Mirador Basin, which was largely abandoned by 150 AD. Regional abandonment may have been linked to the destruction of forest resources, agricultural land both on the uplands and in portions of the bajos, and perhaps to the onset of more frequent droughts suggested in several paleoenvironmental records (see Sect. 23.2.3 above).

23.3.3 La Milpa

One hundred kilometers due east of El Mirador is the ancient city of La Milpa, located in the Three Rivers region of northwestern Belize. The site center is situated on a high karst ridge amidst a series of upland bajos that today contain seasonal swamp vegetation (Dunning et al. 2002). Investigations show that the small (ca. 2 km^2) Far West Bajo on the northwest side of La Milpa contained a perennial wetland and areas of permanent open water prior to about 100 AD. We attribute this transformation from a perennial to seasonal wetland largely to anthropogenic sedimentation associated with Preclassic deforestation, cultivation, and erosion in the surrounding watershed. These human-mediated impacts caused long-term hydrologic changes within the bajo itself, though natural climatic drying that peaked in the second century AD may have compounded the anthropogenic hydrologic changes. In either case, the associated erosion and sedimentation also created swaths of alluvial/colluvial soils on the margins of the bajo, which became the focus of intensive agriculture in ensuing Classic times, as is evident in extensive terracing and field wall systems situated on these slopes. The loss of the water resources in the bajo may have also spurred the development of reservoirs in the site center, a transformation that also appears to date to the Late Preclassic/Early Classic transition. Some have suggested that these reservoirs served the dual purpose of providing dry season water for domestic consumption and irrigation (Scarborough et al. 1995), but the capacity of these artificial water bodies is likely to have only barely met the consumption needs of the population in the immediate core area (Tourtellot et al. 2003). Hence, the reservoirs may have had as much a symbolic as practical function, and the ritualized control of water would have been a potent political tool for Maya rulers, especially in a region with a long dry season.

23.3.4 San Bartolo and Xultun

Between Tikal, Mirador, and La Milpa are the ancient towns of San Bartolo and Xultun, which lie 8 km from one another in the northeastern part of the Peten District (Garrison and Dunning 2009). Despite their close proximity, these neighboring communities experienced very different settlement histories. San Bartolo was an important centre in the Middle and Late Preclassic, but was abandoned at the end of the Late Preclassic around 150 AD, only to be lightly reoccupied in the Late Classic around 700 AD. Although excavations are just beginning at Xultun, architecture exposed both at the surface and in numerous looter's tunnels, and inscriptions on the site's many stelae indicate that it too was a sizeable site in the Late Preclassic, but, unlike San Bartolo, went on to grow into a large and important Early, Late, and Terminal Classic center.

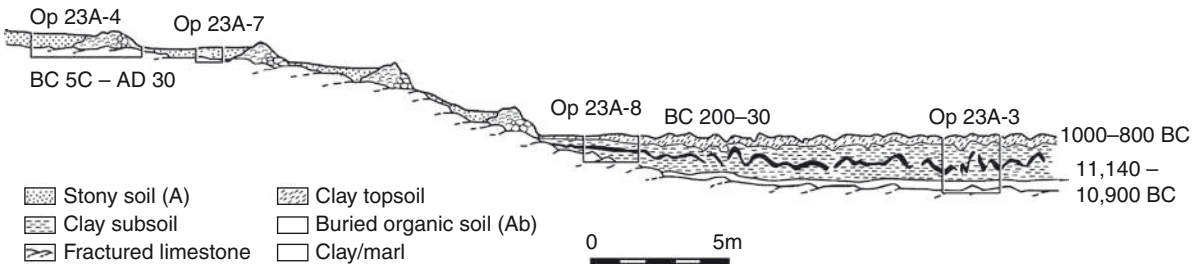

Fig. 23.4 Cross section of the southern margin of Bajo Donato near San Bartolo, Guatemala. Vertical and horizontal scales are identical. Dates are calibrated 90% probability ranges

Paleoenvironmental investigations in two bajos near San Bartolo provide some clues as to what happened in this region at the end of the Preclassic. A core taken from the Aguada Tintal, a reservoir pond in a small bajo northeast of San Bartolo, contained pollen from maize, manioc, and cotton dating to the Middle Preclassic, ca. 500 BC. Investigations in the adjacent Bajo Donato indicate increasing sedimentation throughout the Middle and Late Preclassic periods as surrounding sloping land was cleared of forest for farming. By the first century AD, Maya farmers had recognized and responded to the soil erosion problem and constructed agricultural terraces on the flanks of the bajo (Fig. 23.4).

Excavations in the small Bajo Majunche midway between San Bartolo and Xultun indicate that a shallow lake existed in this depression around 800 BC and later desiccated, probably due to a combination of anthropogenic sedimentation and regional climate drying. The divergent histories of San Bartolo and Xultun may be connected with how their inhabitants responded to the drying climate. The inhabitants of Xultun invested in the construction of numerous aguada reservoirs; their counterparts at San Bartolo, for unknown reasons, did not. Xultun prospered; San Bartolo was abandoned, only to be reoccupied many centuries later, probably by people from Xultun.

23.4 Early Classic

The Terminal Preclassic (AD 100–250) was marked by both regional-scale and individual site abandonments. The onset of the Early Classic was characterized by a return of relative stability in most parts of the Maya Lowlands. This period also saw significant increases in urban population nucleation both at small and large centers, a change brought about both by increasingly fixed and intensive forms of cultivation, including farming within urban precincts, and by the apparent development of significant trade in foodstuffs, at least in some areas. The dawn of the Early Classic was also marked by the founding of numerous royal dynasties that would hold sway over much of the Maya Lowlands for the next five to six centuries (Martin and Grube 2008).

23.4.1 *Tamarindito: Landscape-Modification and Urban Agriculture*

The ancient city of Tamarindito came into existence in the Early Classic period through the apparent coalescence of several Preclassic villages. Perched on a spur of the 100-meter-high Petexbatun Escarpment, Tamarindito inhabitants looked out over the nearby lake (see Sect. 23.3.1 above). During the Early Classic, Tamarindito, together with the smaller site of Arroyo de Piedra, was the twin capital of a small, regional dynasty that controlled much of the Petexbatun landscape (Demarest 2005).

Over many generations, the people of Tamarindito terraformed the hilly terrain of the growing urban center, stabilizing sloping land and making it sustainably productive by constructing many types of agricultural terraces such as contouring slope terraces, box terraces, and check dams (Fig. 23.5; Beach and Dunning 1995).

Based on their architectural elaboration and midden deposits, many of the urban farmsteads of Tamarindito centered on elite or at least middle class residen-

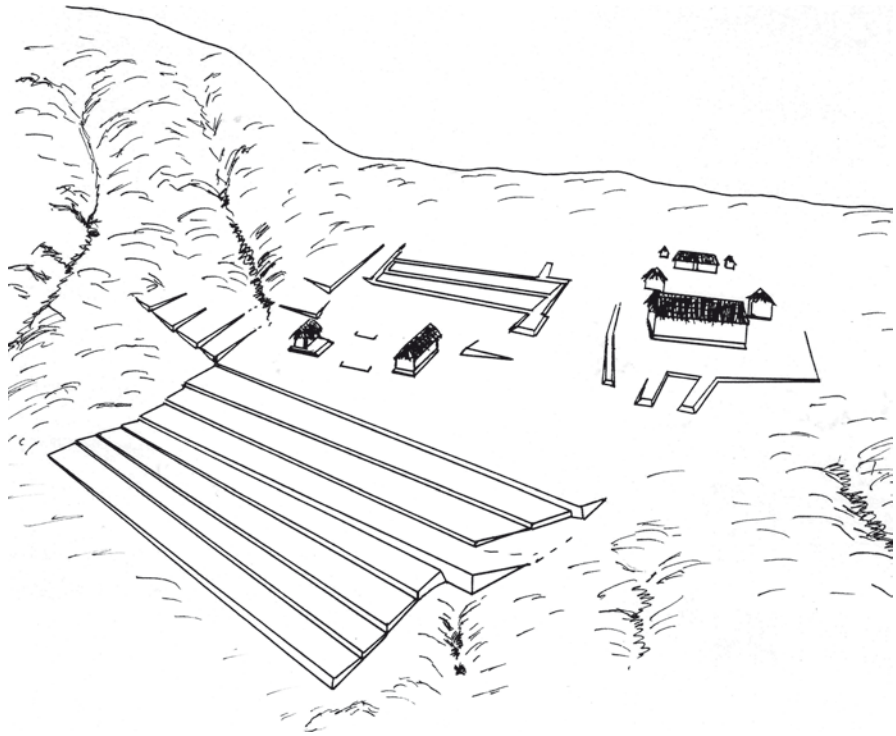

Fig. 23.5 Elite residential complexes and agricultural terracing in the urban zone of Tamarindito, Guatemala. Long terraces in the foreground are about 35 m in length. (After Dunning 2004)

tial groups. Typically these compounds also included lower-status residences, likely lower-status members of the same lineage (Dunning 2004).

The structure of ancient Maya society was largely lineage-based (lineages are descent or name groups in which all members claim descent from an apical ancestor). Individuals and their families were assigned by birth to a lineage and a hierarchical position both within their own lineage and a ranked system of lineages. Lineage status was closely tied to land wealth. Within garden cities such a Tamarindito there was a high correlation between residential location and either prime or well-developed land, likely reflecting the use of the 'first founder' principle. In Yukatek Mayan, for example, the expression 'yax chibal way tiluum' (first founding lineage of the land) captures this principle whereby the first settlers of land claim it as their own. Patricia McAnany (1995) has aptly called the Maya lineage system a crucible of inequality, in which first families enjoyed considerable land wealth and privileged social positions and others farmed less desirable land or labored for the elite. Even within lineages, however, were significant disparities in wealth, which likely accelerated with time as land became increasingly scarce and land inheritance less assured. A study of human skeletal remains from the Petexbatun region indicates that while the average health of the population remained remarkably stable throughout Classic times, the disparity in quality of diet between rich and poor increased markedly over several centuries (Wright 2006).

The vast majority of the ancient Maya were farmers and the vast majority of Maya settlements should be understood first as farming communities (Dunning 2004). A fundamental aspect of many Classic period Maya communities, such as Tamarindito, seems to have been agricultural self-sufficiency, through the use of intensive cultivation of infields within the towns themselves, and the control of production in lands surrounding the town (outfields and tributary settlements). This general characteristic applies to even the largest Classic Maya cities such as Tikal and Calakmul. Nevertheless, although the garden city model of Maya communities certainly applies to many, if not most, ancient Maya communities, there were exceptions in which other forms of economic, political, or other activities were paramount and urban agricultural production played a lesser role in the function of the central place.

23.4.2 Dzibanché: Urbanization in a Wetland Setting

The ancient conurbation centered on the site of Dzibanché (or Tzibanche) is situated on an isthmus of higher terrain that separates two large bajos (Bajo Morocoy and Bajo Acatuch) in southern Quinana Roo state, Mexico. Study of aerial photographs in the 1970s revealed that these bajos contain by far the most extensive areas of wetland fields and associated canals known anywhere in the Maya Lowlands, with field areas covering as much as 240 km^2 (Harrison 1977). Unfortunately, these field and canal systems have never been systematically excavated and are essentially undated. For many years, it was assumed that this agricultural system must date to the Late Classic period, an assumption based on only circumstantial evidence and the widespread belief that population and land use intensity peaked uniformly across the Maya Lowlands in the Late Classic. However, recent excavations within the Dzibanché settlement system, which is surrounded by fields and canals, indicate that this urban center reached its apogee in the Early Classic (Nalda 2005). The conurbation includes four large architectural clusters lying 2–2.5 km from one another and connected by causeways. Residential settlement spreads around and between the centers covering an area of 15–20 km^2. Late Preclassic, large monumental construction is found in both the Dzibanché (Grupo Principal) and Kinichná complexes and extensive areas of residential occupation centring on large aguada*s*. Growth continued at Dzibanché in the Early Classic, and towards the end of that period the site seems to have become the seat of the Kaan dynasty, which may have been centered at El Mirador in the Late Preclassic and shifted to Calakmul around AD 630 (Martin and Grube 2008). The remainder of the Late Classic is more poorly represented (Nalda 2005).

Unfortunately, the large and elaborate system of wetland agriculture surrounding Dzibanché remains poorly documented and large areas have been obliterated by modern development. The degree to which this system co-evolved with the large urban node near its center and other questions such as whether larger canals were articulated as part of the urban plan of Dzibanché remain unanswered. However, Dzibanché and its neighboring wetland field systems give the appearance of a grand experiment in a different kind of Maya garden city, wetter than others. As near Blue Creek (discussed below), these experiments may have been responses to rising water tables and regional climate drying over Maya history.

23.4.3 The Curious Case of Chunchucmil

Not all ancient Maya communities fit the garden city model as outlined above.

Chunchucmil lies some 25 km inland of the Gulf of Mexico on the karst plain of northwest Yucatan, separated from the coast by broad bands of swamp estuary and savannah. In many ways Chunchucmil is the ideal test case for the idea that Maya cities developed with agricultural self-sufficiency in mind (Fig. 23.6). Chunchucmil was among the largest and most densely

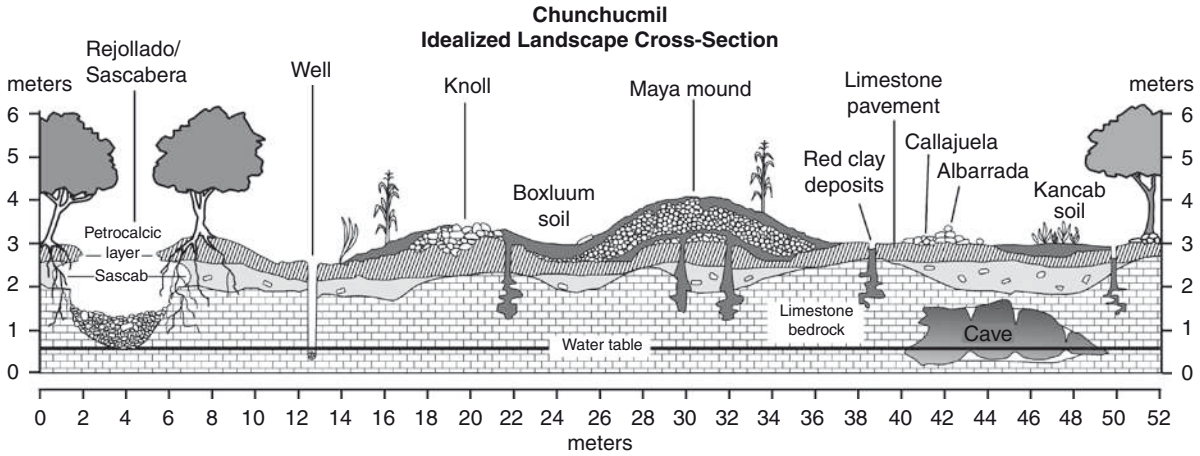

Fig. 23.6 Idealized cross section of the landscape around Chunchucmil, Yucatan

settled cities in the Maya Lowlands; the central urban area (21 km^2) population is conservatively estimated at between 42,400 and 47,600 with densities ranging variably from 1325 to 2975 per km^2 across the area, not including an additional 20–40 km^2 of less dense residential settlement (Dahlin et al. 2005, 2007). These exceptionally high population numbers stand in sharp contrast to the apparent carrying capacity of both the urban area itself and its hinterland. Chunchucmil is situated in what is widely regarded as one of the poorest areas for traditional agriculture in the Maya Lowlands with scant soil cover and relatively low rainfall (~900 mm/year). Despite these limitations, evidence suggests that the people of Chunchucmil made valiant efforts to supply themselves with food through intensive gardening, probably including tree-cropping, pot irrigation, and mining organic soil from the nearby savannah zone to build up raised beds within the city's walled 'solares' (kitchen gardens) (Beach 1998). Recent studies of underlying limestone cavities at Chunchucmil, and near Yalahau (Sedov et al. 2008), have shown significant sedimentation, which may indicate erosion of thicker and more productive soils in antiquity. Nevertheless, even models that incorporate the most creative agricultural strategies and the most conservative population estimates, cannot reconcile Chunchucmil's burgeoning population with the poor carrying capacity of its environment (Beach 1998).

Chunchucmil is not a typical Maya regal-ritual city. Monumental architecture is modest and Classic Maya dynastic attributes such as stelae are lacking. These factors, plus the relative wealth of the city's inhabitants in imported goods, the apparent existence of a central marketplace and manufacturing enclaves, and the city's location between the coast and more productive agricultural land farther inland, have led investigators to suggest that Chunchucmil functioned largely as a trade center, possibly based on its large central marketplace (Dahlin et al. 2007). The city's connection to the coast and its trade routes (as well as salt beds and other marine resources that Chunchucmil may have sought to exploit or control) was apparently enhanced by canals that traversed some intervening terrain. Although originally thought to be a Late and Terminal Classic city, recent work indicates that the city reached its zenith in the Early Classic (Hutson et al. 2008) and declined in size and importance thereafter. This chronology thus predates the major occupation of the agriculturally-rich Puuc region which lies 25–30 km southeast of Chunchucmil, suggesting that the city could have tapped that region's surplus agricultural production either through the intermediary city of Oxkintok, or perhaps directly through seasonal movement of the population into the Puuc.

23.5 Late Classic

The transition from the Early to Late Classic periods was marked by far fewer disruptions than occurred at the end of the Preclassic. Many centers simply continued to grow at the end of the Early Classic. A few centers, however, most notably the large city of Tikal and its allies, experienced a century-long downturn in their fortunes referred to by archaeologists as "the Hiatus" (Martin and Grube 2008). Such downturns seem to have been the result of escalating warfare among Classic polities, most likely related to increasing land scarcity and a growing number of royal descendents, some of whom sought to carve out a place in the political landscape (Demarest 2005). There is, however, some paleoenvironmental evidence suggesting increased drought frequency during the sixth century AD, possibly related to an equatorial volcanic eruption that disrupted climate across widespread areas in the Northern Hemisphere (Gill 2000; Larsen et al. 2008; Rosenmeier et al. 2002). If droughts led to significant agricultural failure during this time, this event may have contributed to the pattern of escalating warfare between centers. But, only one region shows a widespread pattern of site abandonment and for reasons other than drought: the Yalahau region in the northeast suffered changing groundwater levels that may have disrupted wetland agriculture (Fedick and Morrison 2004).

23.5.1 Coba

The largest urban center in the northeastern Maya Lowlands was Coba, which reached its zenith in the Late Classic and sprawled over some 30 km^2. Coba enjoyed a number of significant environmental advantages. Located in a comparatively elevated and well-drained southern portion of the Holbox Fracture Zone, it was blessed with several perennial lakes, and was not as adversely affected by changes in groundwater level that created havoc further to the north in Yalahau, though water levels in the Coba lakes have clearly

fluctuated (Leyden et al. 1998). It also benefited from the atypically high and dependable precipitation associated with the Coba rainfall anomaly in northeastern Yucatan. Karst solution depressions within the Holbox Fracture also contain deeper, more humid, soils than those outside. In short, the residents of Coba enjoyed relative advantages in drinking water supply, soil, and abundant rainfall to grow crops. These factors aided in the development of an extensive urban zone where staple crops, tree crops, and other economic plants were grown extensively and intensively. The city had sprawling residential zones with open garden spaces carefully partitioned by networks of field walls (Folan et al. 1983), though even this fortunate place may have relied on imported food during its zenith. These favorable local environmental factors may also help explain Coba's relative longevity. The city reached its apparent zenith in the seventh and eighth centuries AD, declined in the ninth century (possibly as the result of conflict with Chichen Itza), but continued to be an important town through the Postclassic (Leyden et al. 1998).

23.5.2 Caracol: Garden City Extraordinaire

The large urban site of Caracol is situated on the Vaca Plateau on the northwest flank of the Maya Mountains of Belize. Paralleling what the Maya of Dzibanché accomplished in the bajos of southern Quintana Roo, the Maya of Caracol transformed the hillslopes of a large swath of the Vaca Plateau into a systematically agro-engineered landscape (Chase and Chase 1998). The lithology of this region (horizontally bedded and strongly outcropping limestone) may have aided the Maya in this effort, but human agency was clearly paramount in the construction of agricultural terracing on an unrivaled scale. Caracol's population may have been as high as 115,000–150,000 in ca. 700 AD. This huge and dense population may suggest that its unprecedented investment in terracing (for the Maya) was an attempt to feed itself, although production of other non-food economic crops such as cotton to support urban industry is also possible (Chase and Chase 1998). Caracol's elaborate settlement and terrace systems have been invoked as evidence of centralized organization and control of agricultural production (Chase and Chase 1998), although equally or more extensive and intricate systems of terracing in the Andes are arguably the product of collectively organized labor and planning by farmers (Erickson 2006).

Caracol was intimately involved, and indeed a major player, in the sustained conflict between Calakmul and Tikal that dominated significant aspects of Classic period geopolitics in the Southern Maya Lowlands (Martin and Grube 2008). In particular, Caracol appears to have contributed to the military success of the Calakmul alliance in the sixth and seventh centuries AD over Tikal and its allies. This was notably the period of Caracol's greatest urban growth and the period of most intensive terrace construction. It is unclear whether Caracol's success in warfare led to its growth during this period or whether its growth and productive agricultural system contributed to its success in warfare—or whether these two attributes were mutually reinforcing trends. As noted above, drought may have afflicted the central lowlands in the sixth century helping foment conflict between rival communities.

23.5.3 Tikal: Agroforestry and Temples

Situated near the southern end of the central Peten karst plateau, Tikal is often used as the archetypal large Classic Maya city. It indeed has typical elements of ancient Maya towns, with an elaborate core of elite residential and other monumental architecture and an extensive residential zone with large amounts of open space, presumably left open to incorporate intensively cultivated gardens and infields. Tikal is situated on an area of higher ground between two large bajo systems, the Bajo de Santa Fe and the Bajo Socotzal.

Early Colonial sources from several parts of the Maya Lowlands describe the existence of ancestral estates, including managed forests under the control of socially prominent lineages (McAnany 1995). These estate forests likely included a wide variety of economically useful tree species such as 'chicozapote' or 'sapodilla' (*Manilkara zapota*) and 'ramon' (*Brosimum alicastrum*). Estate forests may well have been the source of timber used in the construction of monumental architecture, such as the enormous wooden beams (lintels) used in some temples and palaces.

Many paleoenvironmental and archaeological sources indicate that the lowland forest retreated

as population grew during the Late Classic. In this context of declining forest reserves, the demand for large beams used in monumental construction would have been increasingly difficult to meet. A study by David Lentz and Brian Hockaday (2009) of the pattern of timber use in Late Classic temple and palace construction at Tikal suggests that even the rulers of this large city and kingdom had trouble obtaining the wood they desired. After a period of stagnation and decline associated with several military defeats, Tikal's fortunes improved dramatically after 695 AD. Between 695 and ca. 800 AD Tikal rulers engaged in an unprecedented building campaign, including numerous expansions of the royal palace (Central Acropolis) and the erection of six towering temple pyramids (Temples 1–VI) that have become the icons of this ancient city (Martin and Grube 2008). At Tikal, as at many other Classic Maya cities, the wood preferred for lintels in otherwise masonry buildings was chicozapote (*Manilkara zapota*), both a fine lumber and fruit tree. This tree is a relatively slow-growing hardwood found on well-drained upland terrain. Lentz and Hockaday found that the monumental architecture erected between about AD 730 and AD 750 employed massive beams of chicozapote. Between about AD 750 and AD 790, builders switched to using beams of 'palo de tinto' (*Haematoxylon campechianum*), also known as logwood. Palo de Tinto is much harder to harvest and cut, and is found in the bajos located in the hinterlands of Tikal. This switch to palo de tinto suggests that available supplies of chicozapote had been exhausted. By about AD 810, however, chicozapote was again in use in monumental construction, though the beams being employed were much smaller and likely taken from immature trees. Not long after AD 810, the construction of major monumental architecture at Tikal effectively ceased and the city diminished until it was finally abandoned some 100 years later.

23.5.4 La Milpa: Late Glory, Rapid Decline

In contrast to Tikal, La Milpa was a community of relatively modest size until the eighth century AD, when it experienced explosive growth of residential population (to about 46,000 in a central area with a 5 km radius) and monumental construction (Hammond and Tourtellot 2004). This rapid rise in population has prompted speculation that the city and region experienced substantial immigration at that time, most specifically from the Tikal region, which perhaps pushed the region over its sustainable carrying capacity (Hageman and Lohse 2003). During that period, a huge investment was made in field walls and terracing in many both urban and rural contexts. Gair Tourtellot has suggested that by the early ninth century AD, the area around La Milpa may have become a landscape of desperation, with every scrap of cultivable land pressed into service and hardscrabble conditions prevailing in the region's farmsteads (Tourtellot et al. 2003). Food may also have been brought to La Milpa and other centers by developing market systems (Scarborough and Valdez 2003). Nevertheless, La Milpa was rapidly abandoned prior to about AD 830. The changing landscapes around La Milpa are reflected in the pollen recovered in a sediment core taken in 2003 from Lagunita Elusiva, an aguada in the eastern exurbs of La Milpa (Fig. 23.7).

Although few, small house mounds lie near the aguada, there are many agricultural field walls. It is not known when the aguada was either first constructed, or when it was modified from a shallower natural depression to increase its water-holding capacity. However, it appears that sediment was allowed to accumulate in at least the deepest section of the aguada after about AD 400; that is, accumulating sediment was not removed. Pollen from the seventh and eighth centuries shows a very strong human-disturbed/modified-forest signal, most notably high percentages of Poaceae (grasses), Asteraceae (Asters), and *Zea mays* (corn). *Zea* percentages range as high as 5–6%, indicating the cultivation of large quantities of maize close to the aguada. This, along with the network of field walls, suggests sustained, intensive farming. Around AD 800–900, there is a dramatic decrease in cultigens, a large spike in fern spores, followed by an increase in high forest arboreal species (Combretaceae). The fern spike may well represent an incursion of bracken fern (*Pteridium aquilinium*), an aggressive species that thrives in nutrient-poor soil and is a well known invasive in depleted fields in the Southern Maya Lowlands and is an inhibitor to succession (Pérez-Salicrup 2004). By AD 900, the area around the aguada was largely, if not completely abandoned and recolonized by upland forest.

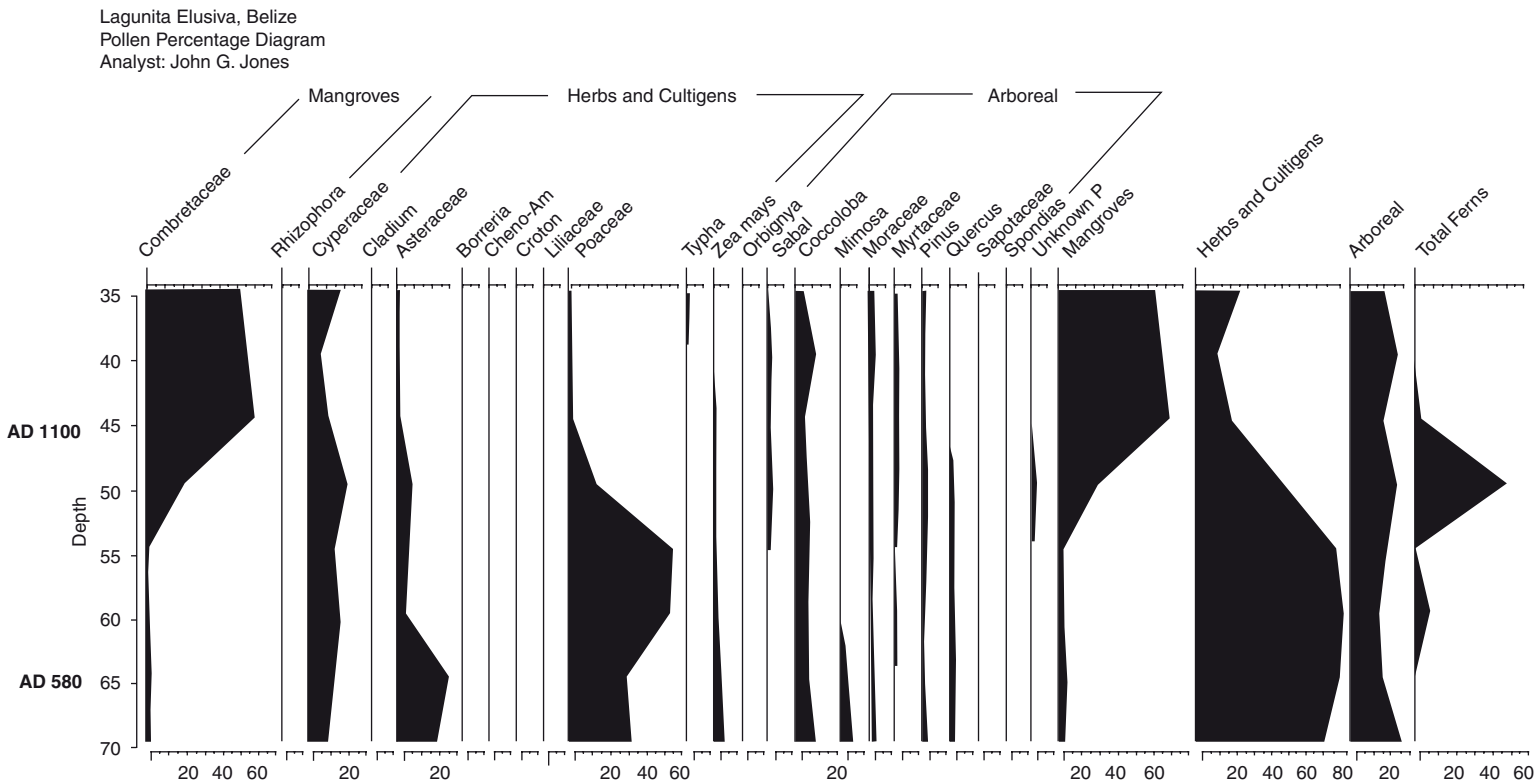

Fig. 23.7 Pollen frequency diagram for Lagunita Elusiva, an aguada on the urban periphery of La Milpa, Belize. (Pollen analysis by John G. Jones)

23.5.5 Dos Pilas: Urban Predator

In the mid seventh century AD, the Petexbatun region came under the political sway of a new center, Dos Pilas (Houston 1993; Martin and Grube 2008). Apparently established by an intrusive rogue dynasty from Tikal, Dos Pilas was located on marginal land and appears to have invested little labor in developing local agricultural potential. Rather it seized control of nearby centers such as Tamarindito that had a long history of landscape modification and intensive agricultural production. In short, Dos Pilas was a predatory capital, exacting tribute through expansionistic military domination. The fall of the Dos Pilas polity a century later in the 700 s ushered in a period of escalating regional warfare (Houston 1993; Demarest 2004). One effect of this warfare was to increasingly concentrate population into defensible positions on the uplands of the Petexbatun Escarpment. Initially walls were used to demarcate parcels of rural farm land as cultivation was intensified across the uplands. Eventually, even the rural farmsteads themselves were fortified as political authority in the region disintegrated (O'Mansky and Dunning 2004).

23.6 Terminal Classic

The Terminal Classic period in the Maya Lowlands was, overall, a time of spreading social chaos and declining populations. Embedded within this time period was the complex phenomenon often referred to as the Classic Maya Collapse. The collapse of Classic Maya Civilization is sometimes portrayed as an abrupt and nearly complete depopulation. Although some regions of the Maya Lowlands indeed experienced significant population declines, elsewhere it was less dramatic. The archaeological record remains frustratingly ambiguous concerning how rapidly population collapsed in many areas. In some places there are indications of a prolonged, multi-generational decline, while at others there seems to have been abandonment in a matter of a few years, or even days (Dahlin 2000; Demarest 2004). Thus the story must have varied from place to place according to differential resilience and the severity of both historical and environmental circumstances. In short, the collapse was a prolonged and complex phenomenon that defies simple description or explanation.

As discussed above in Sect. 23.2.3, paleoenvironmental data derived from lake sediment cores taken in several parts of the Maya Lowlands, and elsewhere in the Caribbean, indicate that the Terminal Classic included several periods of intensive drought. Given the dependence of Maya agriculture on rainfall and the difficulties of obtaining drinking water in many areas, Maya Civilization was vulnerable to drought. Hence, it is no surprise that the dry Terminal Classic period was tumultuous. Environmental problems associated with drought would have been intensified by the population growth in the preceding centuries of the Late Classic that created a need for higher levels of agricultural production. Severe or prolonged droughts would have challenged the Maya ability to feed themselves and threatened the stability of their political system. However, Normark (2006) notes that models of drought impacts on the pre-Hispanic Maya overemphasize descriptions of devastating droughts from the Spanish Colonial period, during which time much of the resilience attributable to earlier Maya adaptations may have been destroyed by the mandates of the colonial administration. In particular, the Spaniards prevented Maya population dispersal to areas with back-up water sources in times of drought and they siphoned off food supplies from many regions.

Although regional droughts may have played a major role in the depopulation of many Maya centers, droughts do not explain many aspects of the collapse. In places like the Petexbatun region, the Classic Maya political system was unravelling even before evidence for drought is found in the paleoenvironmental record. Increasingly belligerent relationships between competing royal dynasties and a political system dependent on an insatiable demand for tribute likely were major contributing factors to the collapse (Demarest 2005). The disintegration of kingdoms appears to have spread like a contagion through wide areas of the Maya Lowlands between about 750 and 950 AD (Webster 2002). By the end of that period, the Classic Maya political system with all its trappings of elaborate dynastic monuments and inscriptions had essentially disappeared. Nevertheless, in many areas population levels, while diminished, remained relatively high, and new and transformed variants of Maya culture developed in the ensuing Postclassic period.

23.6.1 The Decline of the Puuc Cities and the Rise of Uxmal

The Colonial Era town of Santa Elena sits within the middle of the broad structural valley that earth scientists have designated the Santa Elena Physiographic District (Wilson 1980). The pre-Hispanic name for Santa Elena was Nohkakab (the place of good earth), a name fitting to this valley that contains extensive tracts of fertile Mollisols and Alfisols, and the richest agricultural zone in the northern lowlands. Along with the Bolonchen Hills, a broad expanse of cone karst hills and solution valleys, archaeologists refer to this area as the Puuc Zone—culturally distinguished by a distinctive style of concrete core/decorative veneer stone architecture that appeared late in the Late Classic period.

Due to an almost complete lack of natural water sources, year-round settlement in the region was only possible through the capture and storage of rain. This feat was largely accomplished in the Puuc through the construction of thousands of underground cisterns ('chultuns') and associated collection surfaces. However, variation in the lithology of surface bedrock made the construction of chultuns much easier in some places than in others, a factor that likely shaped the distribution of settlements across the region and the residential patterns within sites

The eighth century AD Puuc community of Sayil has been described as a classic example of a garden city (Tourtellot and Sabloff 1994). The oldest and largest lineage residences at Sayil are found immediately adjacent to the most favorable tracts of agricultural land within the urban zone. Geoarchaeological studies indicate that the people of Sayil intensively farmed the land adjacent to their homes, likely growing a great variety of vegetables and fruits, including large quantities of maize and other staples. Later residential compounds filled in vacant land and peripheral areas. Settlement patterns studies indicate that Puuc cities and towns were formally bounded and their populations were perhaps reined in by strict control over the construction of chultuns needed to survive the dry season (Dunning 2004). Rural lands between towns were only seasonally occupied and likely farmed on an extensive basis.

The late ninth century rise of Uxmal as the paramount urban center in the Puuc has often been viewed as the apogee of regional Maya culture and a curious exception to the decline of Classic Maya Civilization that occurred in most other regions at that time. However, the large majority of Puuc centers, including Sayil, were themselves in steep decline by the last decades of the ninth century AD (Carmean et al. 2004). Given the complete dependence of the Puuc population on rainfall, it would have been particularly vulnerable to droughts of any significance and the depopulation of many centers in the latter half of the ninth century may have been, in part, attributable to this vulnerability (Dunning 1992). On the other hand, Uxmal underwent an unprecedented program of monumental architectural construction towards the end of the ninth century AD, including the building of the House of the Governor and Nunnery Quadrangle, two of the most stunning examples of Maya architecture ever erected. The late expansion of Uxmal may well have been at the expense of other communities in the Puuc as reflected in its bellicose and militaristic art and iconography. It is possible that Uxmal was preying on neighboring polities already under stress, perhaps from drought and crop failure in an already over-taxed regional agricultural system. Uxmal's method of population concentration may be reflected in its investment in numerous sizeable aguada reservoirs. Uxmal is situated along an unusual series of fractures that created a local abundance of trough-like sinkholes, at least partially plugged with clay sediments. Here, the Maya adapted these sinkholes into reservoirs. Uxmal thus had a natural advantage with regard to concentrating a large urban population during the troubled times of the late ninth century. In this light, Uxmal's late florescence may be less the apogee of Puuc Maya culture than its last gasp (Prem and Dunning 2004)

23.6.2 Successful Adaptations to Large Scale Environmental Changes Around Blue Creek

Unlike the other cases, the region around Blue Creek in the Three Rivers Region of northwestern Belize lasted from the early Middle Preclassic into the Terminal Classic. It even has evidence of Archaic and Postclassic occupations. This region had a fortunate, ecotonal location, situated near the perennially wet coastal plain and river valleys, the fortress-like high ground of a steep escarpment, and deep, well drained back slope,

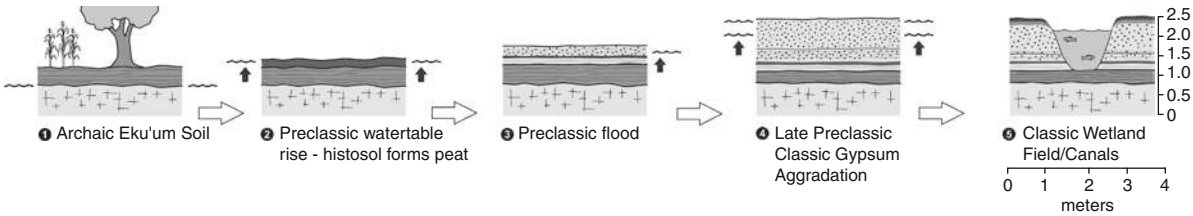

Fig. 23.8 Model of wetland evolution near Blue Creek, Belize

and bajo soils. Population estimates of the site proper are not high, but it was surrounded by numerous other smaller sites that in aggregate add up to a significant regional population of 12,500 (Guderjan 2007). These rural sites clustered around both the thick, upland soils and bajos for agriculture, clay, lime, and lithic sources and the wetlands for a range of resources that occur in these productive ecosystems. Ancient Maya farmers had many options in this landscape, including longer growing seasons in the bajo areas with high water tables, recessional farming in the floodplains, and perennial wetland systems.

The Blue Creek region provides a significant example of both ancient, intensive wetland agriculture and Maya adaptation to environmental changes. In the Archaic period, the wetlands of today were a varied combination of well drained and seasonally wet soils. Archaic to Preclassic farmers were modifying this landscape with slash-and-burn agriculture to grow maize and other crops (Fig. 23.8). But in the Preclassic, as sea levels lifted water tables, these fields became submerged, and upland erosion and large-scale flooding, some driven by a mega flood, started to bury fields. The continued rise of a water table saturated in calcium and sulfate caused precipitation of gypsum that buried the fields further by another meter. In response, from the Late Preclassic to Late Classic Maya farmers dug canals to drain and reclaim at least 7 km^2 of fields to grow corn and a variety of other crops (Beach et al. 2008, 2009; Luzzadder-Beach and Beach 2009).

Ancient Maya reclamation ranged from smaller-scale, piecemeal adaptations at the site of Chan Cahal to pre-planned, larger scale systems, including the Terminal Classic and later Birds of Paradise fields. Although much of the region's upper (later) archaeological stratigraphy has been disturbed by modern farmers, there is significant evidence of Postclassic occupation around and in some of these wetland fields. Thus, the Blue Creek region experienced large-scale environmental changes but the Maya adapted through the Terminal Classic with sophisticated, intensive farming practices, likely abetted by intra-regional trade in this heterogeneous area. Moreover, this region with its wetlands and rivers, similar to the pattern at the nearby site of Lamanai, displays evidence for cultural continuity, but with diminution into the Postclassic.

23.7 The Postclassic and Beyond

Overall population numbers across the Maya Lowlands in the eleventh century AD were probably at their lowest levels since about the fifth century BC. Nevertheless, Maya Civilization persisted in many locations, most notably in the eastern-most and northern-most parts of the lowlands. By the fourteenth century AD, population levels were again increasing significantly and some areas, like the Peten Lakes District and Yalahau, which had been largely depopulated for centuries were once again thriving centers. Across the lowlands, Postclassic communities exhibited much less emphasis on monumental architecture and a greater focus on mercantilism and pan-regional commerce, especially along coastal trade routes.

Reflecting the lower population densities in most areas, relative to Classic times, swidden agriculture predominated in most regions. Spanish accounts from the sixteenth century describe a system in which fields were cultivated for 2–3 years, followed by 8–10 years of forest fallow, though intensively cultivated gardens and orchards were also commonplace. In the century following Spanish contact and the catastrophic introduction of Old World epidemic diseases, population levels in the Maya Lowlands plummeted with regional decreases as high as 90%. Spanish overlords forced remaining native people to relocate to small, more easily controlled enclaves, leading to abandonment of many areas. With population levels remaining low in the ensuing 2–3 centuries, long-fallow swidden

farming became widespread across the lowlands—and became fixed in the minds of scholars as the normal system of cultivation among the Maya. This perception of the Maya Lowlands as having low population densities, low agricultural productivity, and largely vacant ceremonial centers, became the model of the Maya as an anomalous, mysterious tropical civilization. This model persisted into the 1960s until many studies pursued new questions with a host of new methods that revealed the much more complex nature of Maya Civilization (Dunning and Beach 2004).

23.8 Discussion

The examples considered herein illustrate the variability of landscapes that existed in the Preclassic and Classic Maya Lowlands. This variability was the product of spatial differences in the underlying environment, several environmental changes, and Maya adaptations over time. On a basic level, spatial variation in the adaptive strategies used by the Maya under different environmental conditions is expressed in whether Maya peoples chose to focus agriculture in wetlands or dry uplands, how they dealt with the annual problem of dry season water availability, and how diverse and intrinsically fertile soils were across the broader landscape.

Over time, the Maya devised many successful site-specific adaptations to fulfil their basic needs in the varied landscape. The environment of the Maya Lowlands was, nonetheless, far from stable and Maya communities either adapted or failed to adapt as circumstances changed. From the perspective of landscape archaeology, the overall trajectory of ancient Maya Civilization is perhaps best represented by a metastable equilibrium model; that is, periods of relative stability punctuated by episodes of significant change. This model is aptly applied to many ancient civilizations where environmental and cultural variables were often delicately balanced and even minor perturbations could have catastrophic results (Butzer 1980). To understand the history of Maya Civilization, both periods of stability and instability must be considered (Dunning and Beach 2000).

Instability was introduced by both natural and human factors. Although the Maya adapted successfully to the generally predictable annual wet-dry (seasonal) rhythm of the lowland climate, longer-term fluctuations such as episodic intensification of the frequency and intensity of drought posed a serious threat to their adaptive strategies. These episodes, plus long-term regional drying trends and sea-level rises introduced both temporary and long-term hydrological changes that sometimes led to major regional abandonment such as in the Mirador Basin, but also to successful adaptations, such as near Blue Creek.

As we study ancient human–environment interactions it is important to bear in mind that the physical evidence for environmental change generated by natural fluctuations and by human activities is often indistinguishable in the paleoenvironmental record (Rosenmeier et al. 2002; Dunning et al. 2006; Beach et al. 2008, 2009; Yeager and Hodell 2009). For example, both soil erosion rates and hydrology are affected by changes in climate or human activity and leave similar signals of disturbance. Similarly, some drought signals, such as palynological evidence of forest loss in the paleoenvironmental record, may result from climate change, from anthropogenic deforestation or a combination of these factors (Yeager and Hodell 2009).

Humans also introduced instability into the regional landscape dynamics. Most simply, population growth over time often necessitated greater amounts of agricultural land, thus depleting forest resources and disturbing the soil cover. In many parts of the world, deforestation has significantly diminished the resilience of human-environment systems (Chew 2007), a problem that was repeated at different times and places in the course of Maya Civilization. As mentioned earlier, the relationship between human population densities and soil erosion, or other forms of land degradation, is not always straightforward and linear. Indeed, there is compelling evidence from the Petexbatun region and the Central Peten Lakes that relatively small numbers of Preclassic farmers generated the greatest amount of soil loss as a consequence of initial forest clearance, when low population densities perhaps created the perception of an inexhaustible supply of land (Dunning and Beach 2000; Anselmetti et al. 2007; Beach et al. 2008). In some instances, disturbances related to Maya activities degraded, but at the same time improved local environments. For example, soil erosion generated by Preclassic agriculture may have contributed to rapid sediment accumulation in some bajos and consequent hydrologic alteration. Although this may have

destroyed important water sources, the alluvial/colluvial aprons of base-rich sediments generated by the upslope erosion developed into prime farmland along the margins of these same bajos (Dunning et al. 2002). In time, the Maya also became conscious of soil erosion. They developed soil conservation technologies and created more stable agricultural landscapes in many areas during the Classic period.

Social or cultural factors could also have introduced instability. A prime example was the enormous demand for lime plaster engendered by the drive to construct ever larger and more elaborate temples and palaces, such as occurred in the Mirador Basin in the Preclassic and the consequent wholesale destruction of forest resources and land surfaces (Hansen et al. 2002; Wahl et al. 2006). In the Late Classic, the apparent proliferation of royal heirs may have exacerbated growing instability resulting from population growth as dynasties fragmented and fought with one another to control labor and land (Demarest 2005; Webster 2002). In the Petexbatun region this social problem was characterized by a century of escalating warfare, and the development of a fortified landscape of fear, preceding regional abandonment.

Today, deforestation in many parts of the Maya Lowlands is proceeding at a rapid pace. Many modern Maya agricultural colonists have moved into places like the Petexbatun region and face a daunting challenge in developing a stable and sustainable landscape -lack of clear or irrevocable land title. Because many of the colonists do not hold secure title to their land and survive largely on a harvest-to-harvest basis, their commitment to land stewardship is minimal. Likewise, in northern Belize, industrialized farming, albeit with secure land tenure, is bulldozing ancient Maya archaeological sites and leaving farmland unprotected in the face of torrential wet season rains. Soil loss in both areas is often horrendous, with whole hillsides denuded of their soil cover within a few years (Beach and Dunning 1995; Beach et al. 2006, 2008). The unfortunate irony is that as forests are cut down and slopes bulldozed across the region, relict agricultural terrace systems are revealed—terraces that had been adaptations to soil erosion and could, under more favorable circumstances, be reconstructed to serve today's farmers.

Acknowledgements We would like to thank the numerous colleagues and students who collaborated in our research and in particular Drs. Sheryl Luzzadder-Beach and John G. Jones. Funding was provided by grants from the National Science Foundation, National Geographic Society, and other agencies.

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